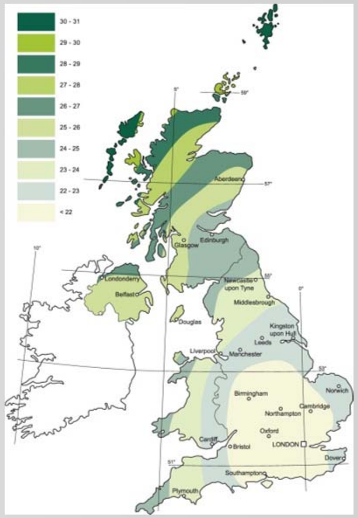
Forum 1: Planning and building

Mounting and substructure and their importance for the power plant?

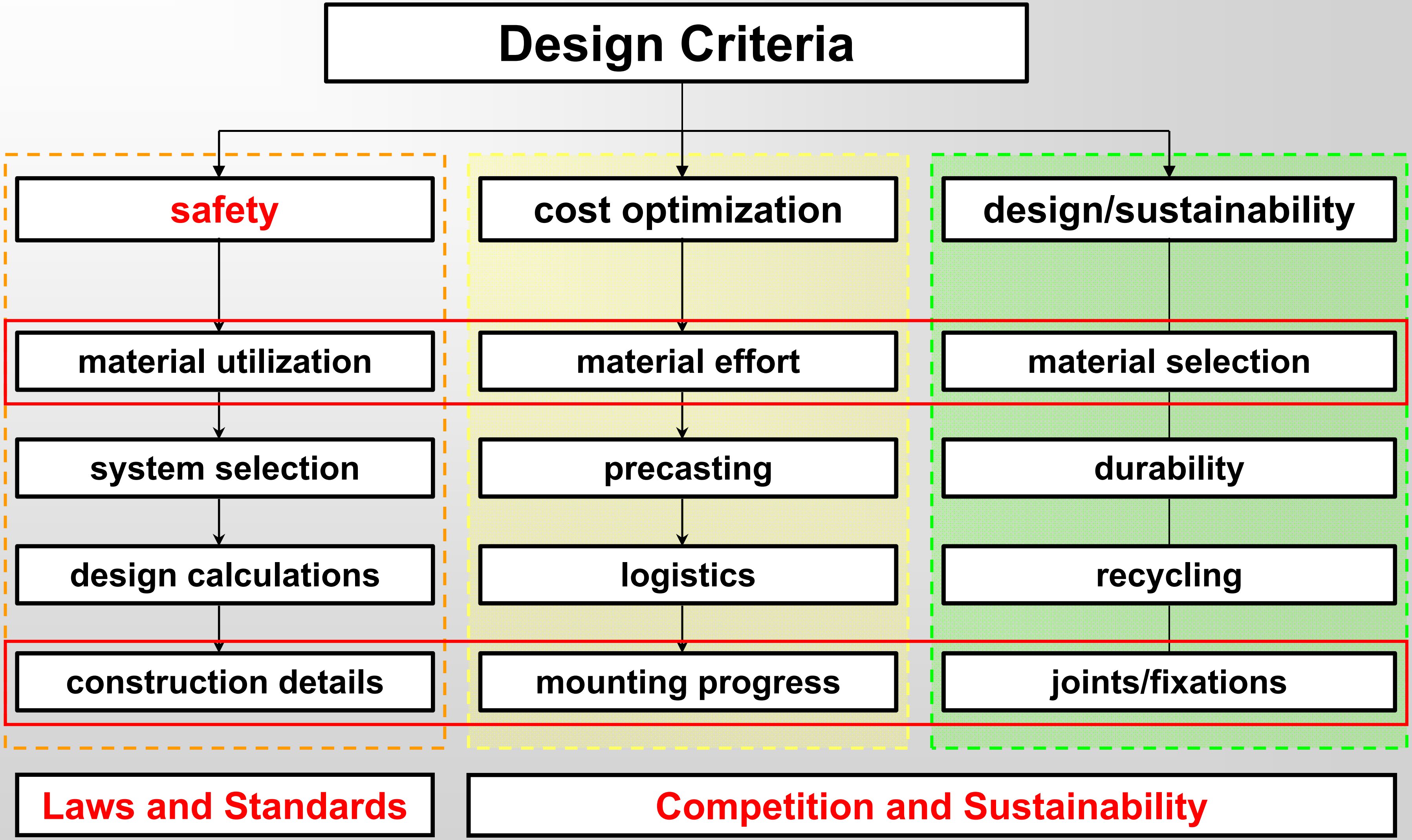
10TH/11TH March, Paris, France

Overview of topics:

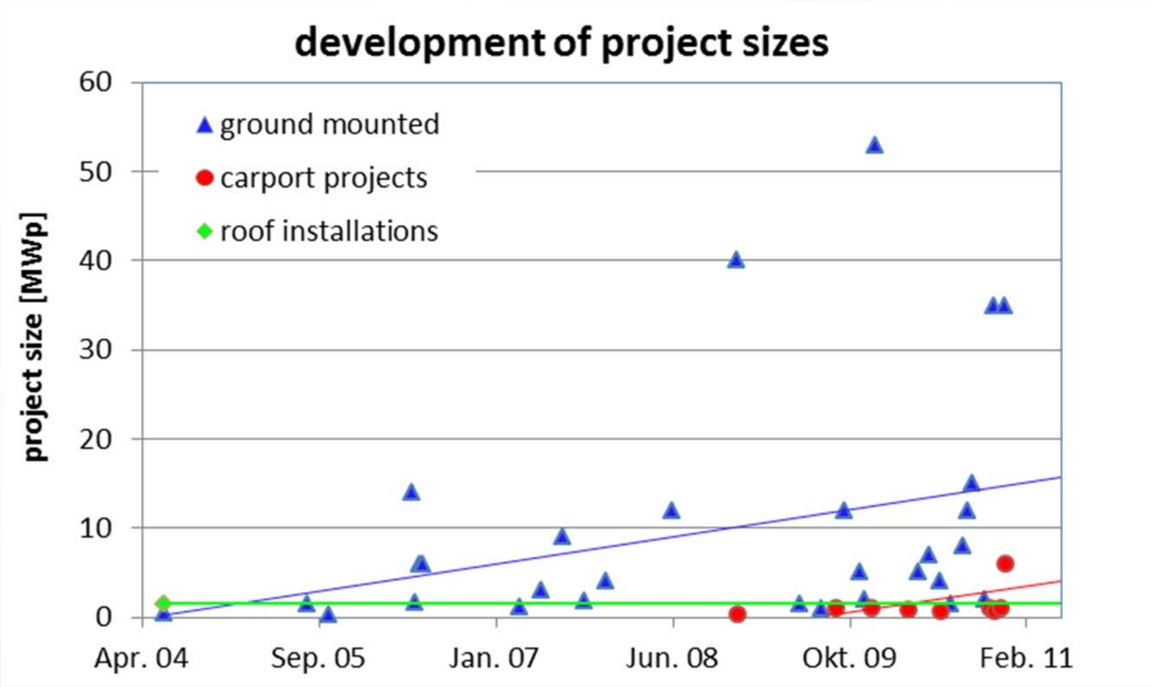
1. Introduction
2. Load evaluation
3. Design calculations
4. Decision criteria for a substructure selection
5. Foundation concepts
6. Mounting progress of foundation concepts
7. Summary



1. Introduction

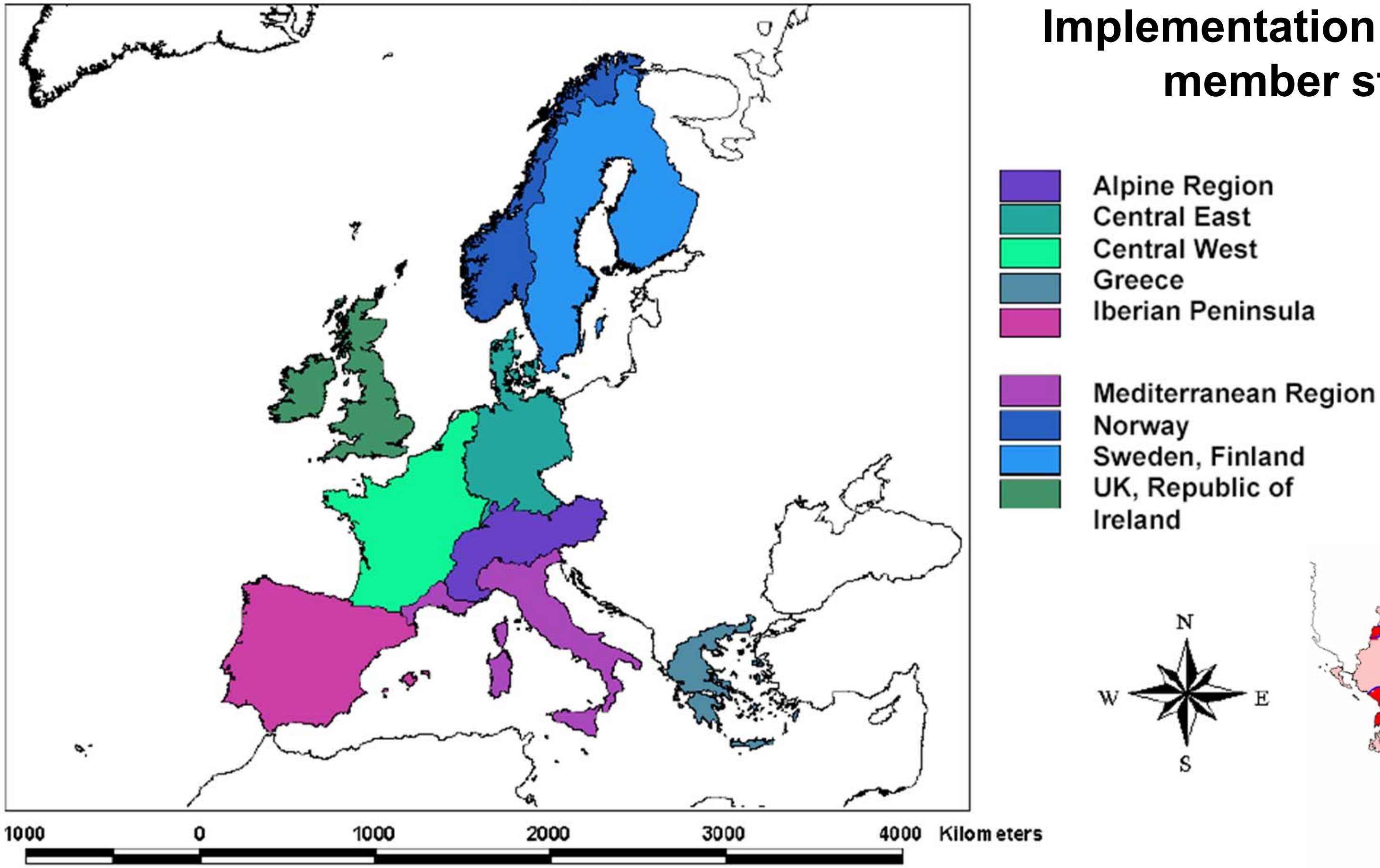


Types of PV-Powerplants



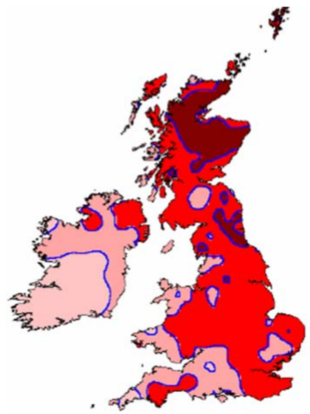
2. load actions

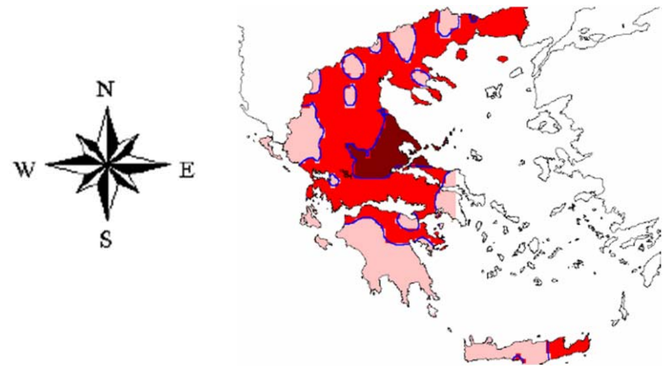
Climatic Regions



Guidelines provided by EU

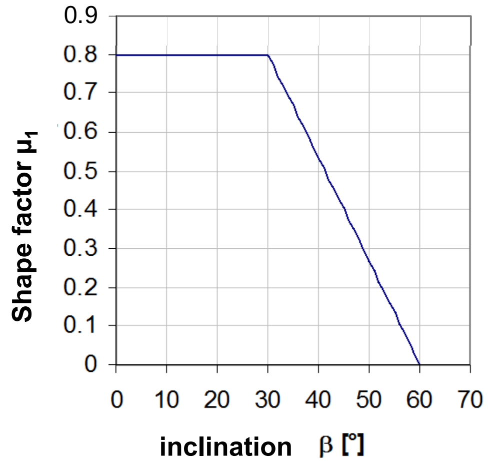
Implementation by individual member states





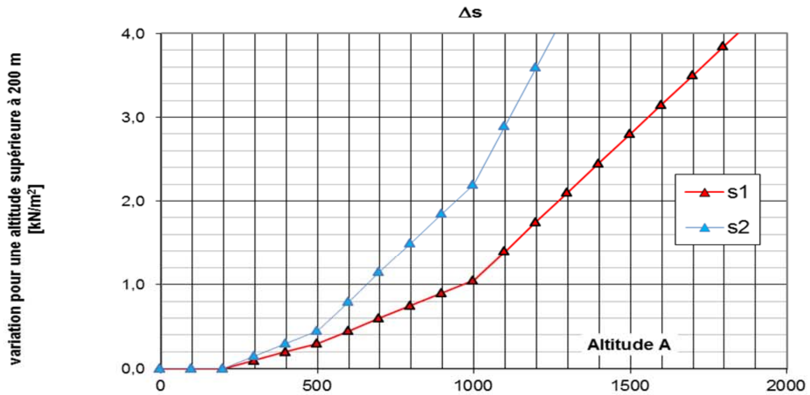
Example: International system for snow load evaluation

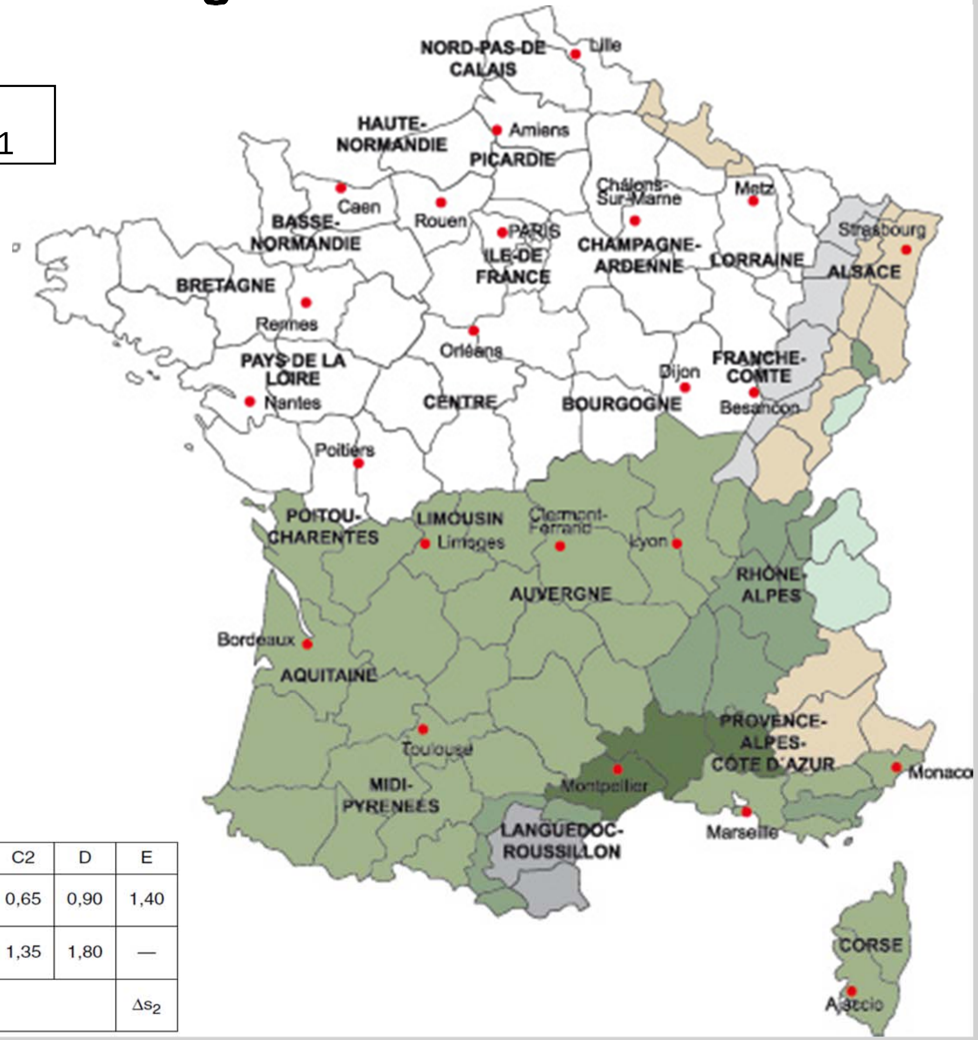
France NF EN 1991-1-3/NA Mai 2007



Snow loads on the ground

$$s = (s_k + \Delta s) \cdot \mu_1$$





Régions :	A1	A2	B1	B2	C1	C2	D	E
Valeur caractéristique (S_k) de la charge de neige sur le sol à une altitude inférieure à 200 m :	0,45	0,45	0,55	0,55	0,65	0,65	0,90	1,40
Valeur de calcul (S_{Ad}) de la charge exceptionnelle de neige sur le sol :	—	1,00	1,00	1,35	—	1,35	1,80	—
Loi de variation de la charge caractéristique pour une altitude supérieure à 200 :	Δs_1							Δs_2

European wind zone map according to Eurocode 1

Basis:

Measurements (188 in D)

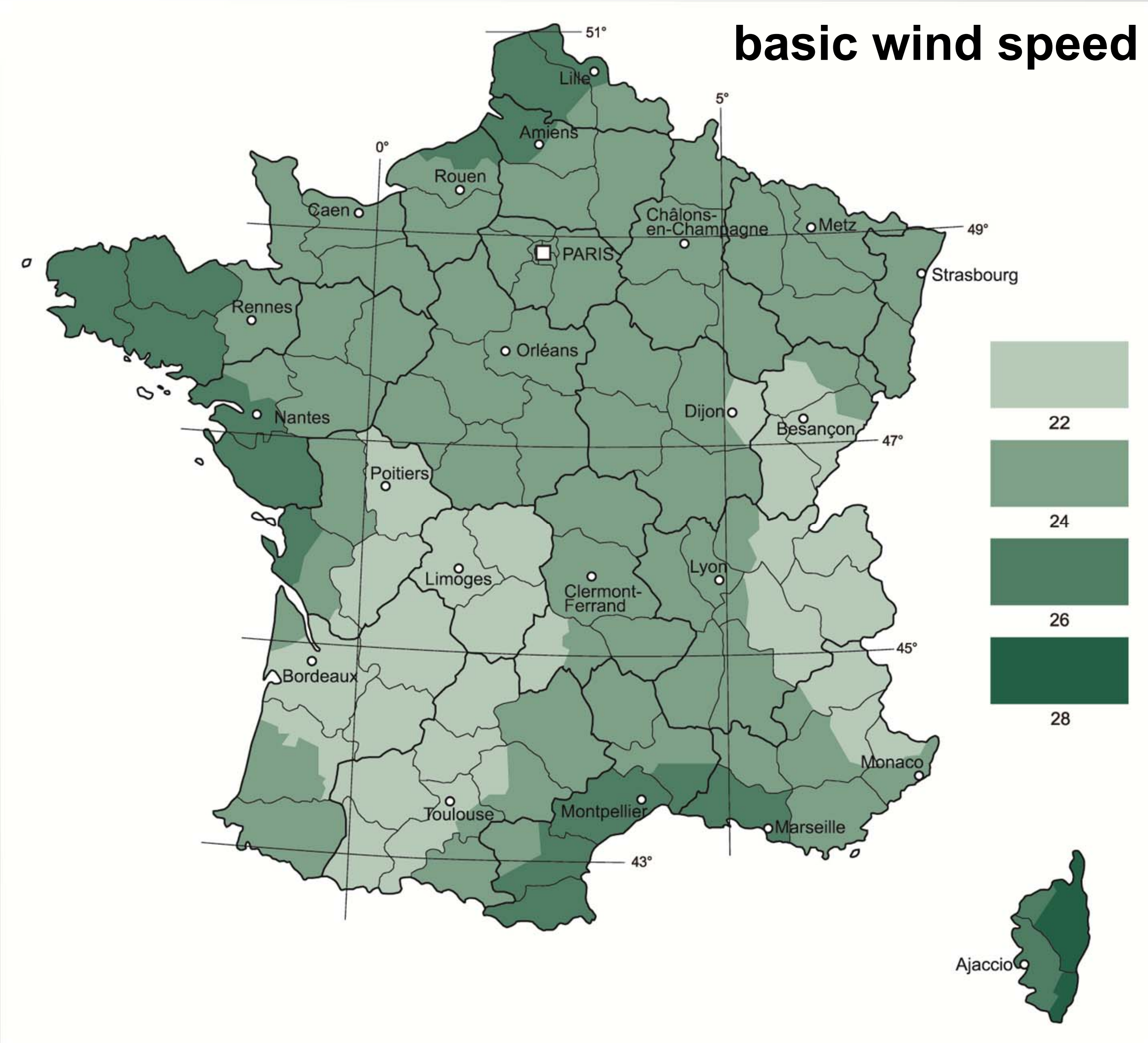
10-minutes median in
10 m height above ground
that occurs once every 50 years

observation period: 40-107 years

contains no gusts

applicable for flat, even terrain

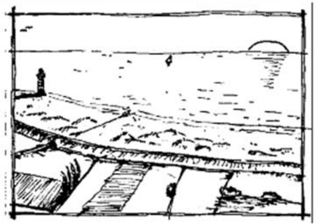
France NF EN 1991-1-4/NA March 2008



Terrain categories according to Eurocode 1

Terrain category 0

Sea, coastal area exposed to the open sea



Terrain category I **(II in France)**

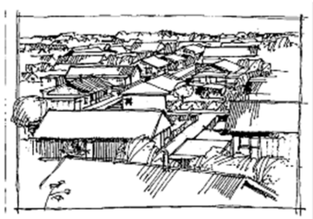
Lakes or area with negligible vegetation and without obstacles

Terrain category II **(III a in France)**

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

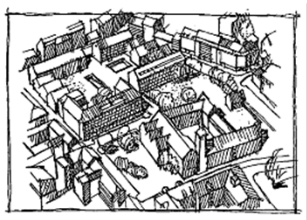
Terrain category III **(III b in France)**

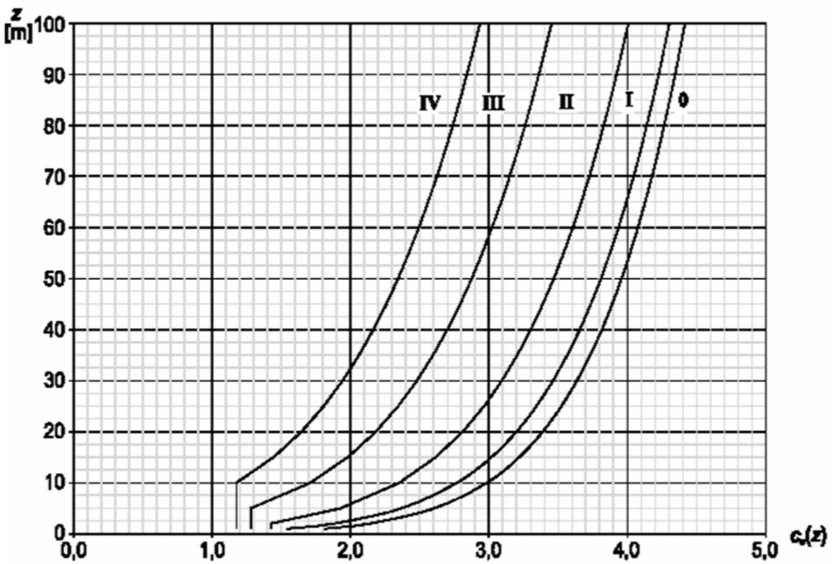
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)



Terrain category IV

Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m





Basis:

$q_b = {}^{1}/_{2} \cdot \rho \cdot v^2$ (basic pressure)

ρ weight of air (1,25 kg/m²)

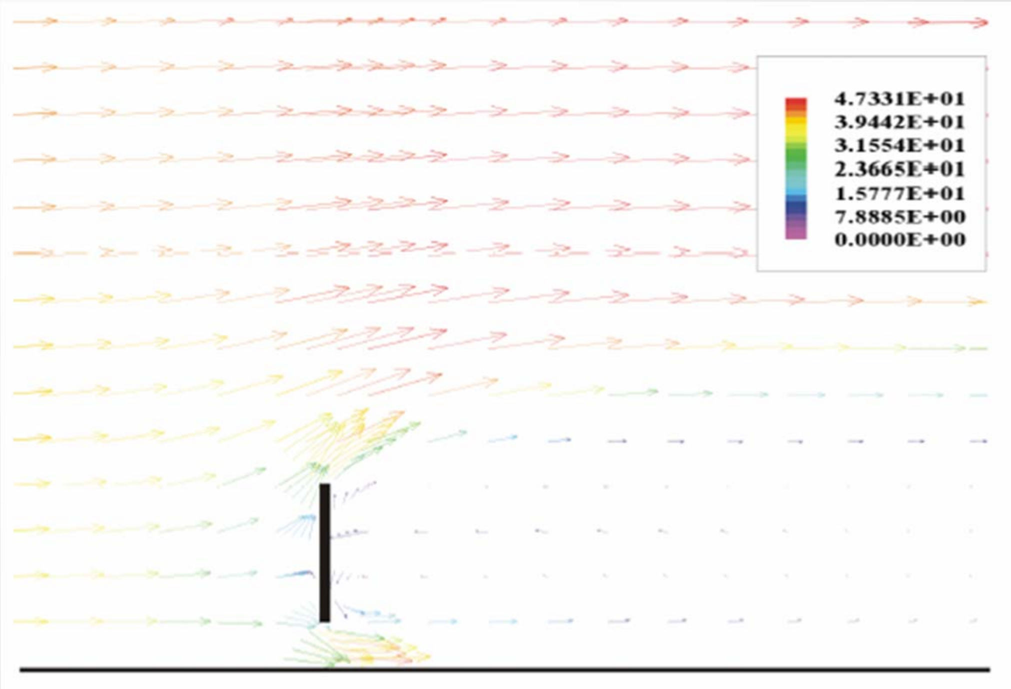
Peak velocity pressure

$q_b(z) = C_e(z) \cdot q_b$

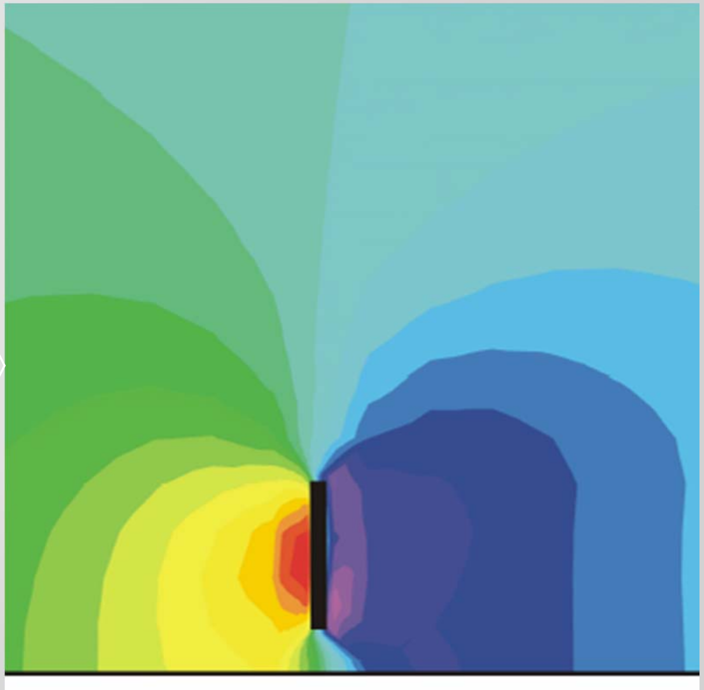
Aerodynamic characteristics

Pressure field if a vertical flow impacts the screen

Strömungsgeschwindigkeiten



Pressure field (qualitative)

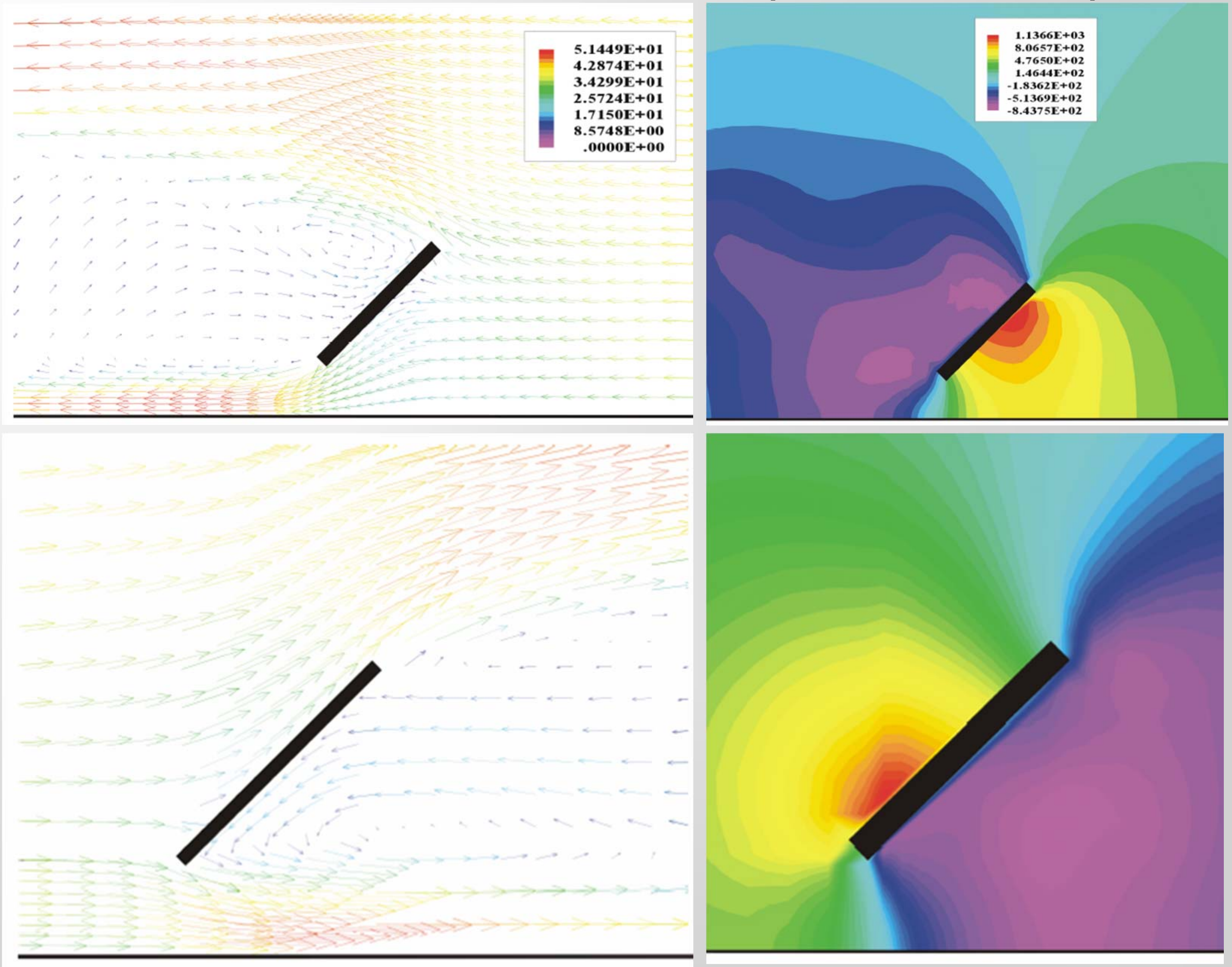


Source: Final report 0327229 A, patronized by the Federal Ministry of Economy and Technology

Aerodynamic correlations

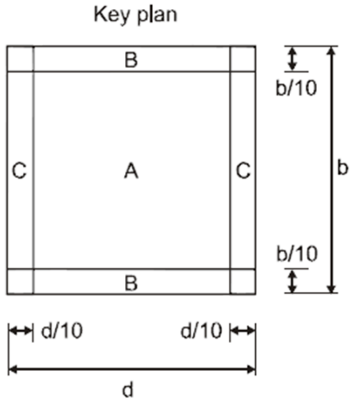
(45° inclination)

Wind direction

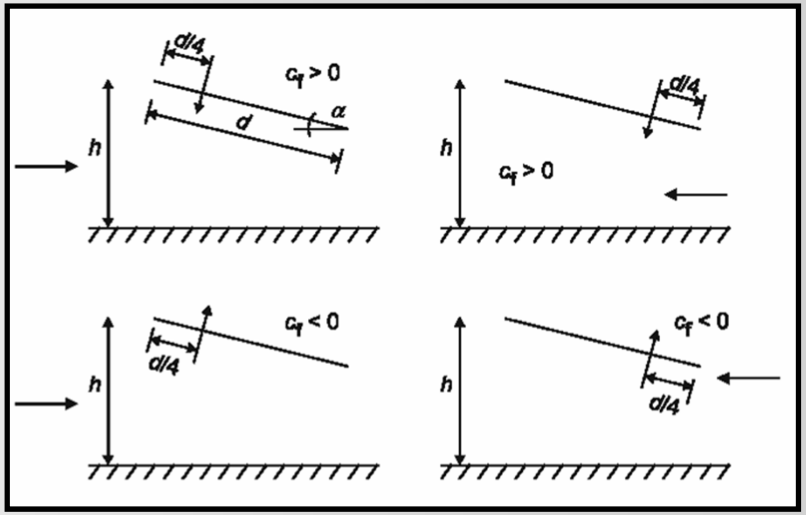


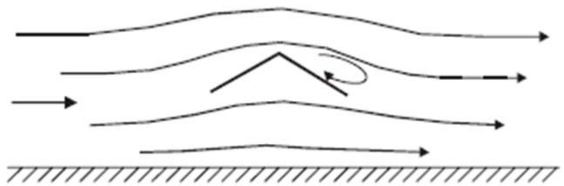
Pressure and Force Coefficients (DIN EN 1991-1-4)

Net Pressure coefficients $c_{p,net}$

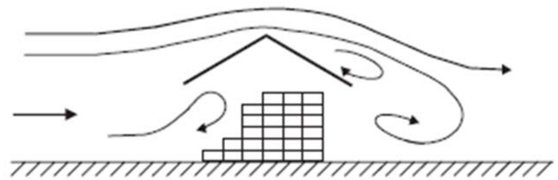


Roof angle α	Blockage φ	Overall Force Coefficients c_f	Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum φ = 0	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum φ = 1	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum φ = 0	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum φ = 1	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum φ = 0	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum φ = 1	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum φ = 0	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum φ = 0	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum φ = 0	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum φ = 1	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum φ = 0	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum φ = 1	- 1,4	- 1,5	- 2,2	- 2,7





Empty, free-standing canopy (φ=0)



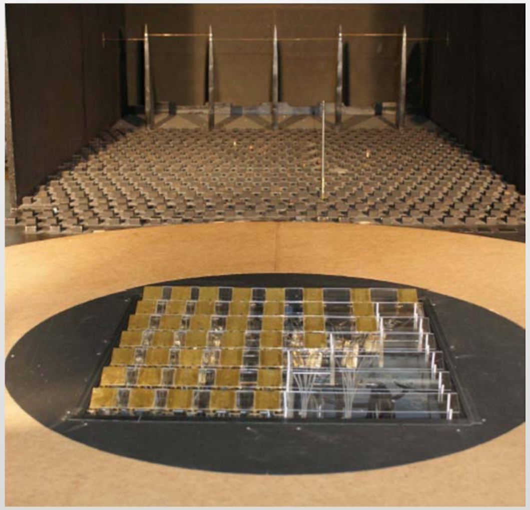
Canopy blocked to the downwind eaves by stored goods (φ=1)

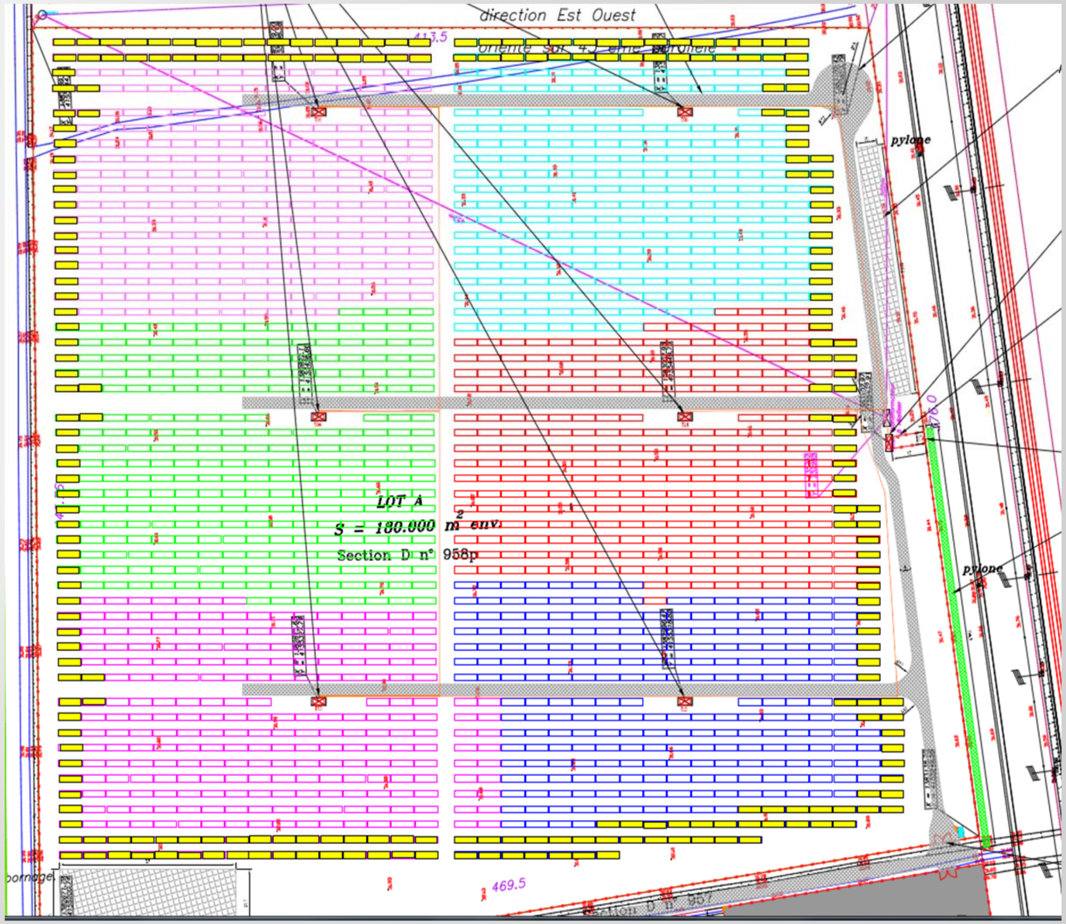
Pressure Coefficients from Windtunnel tests

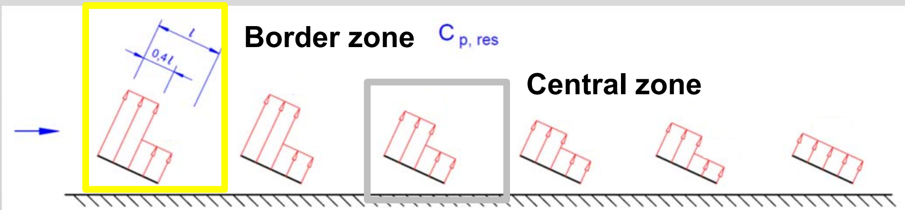
According to Ruscheweyh Consult GmbH

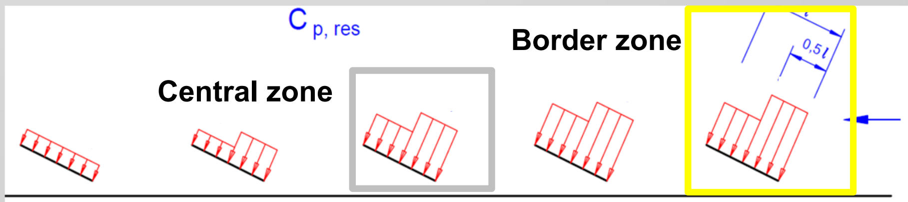
Advantages:

- Load reduction in central areas
- Savings (less posts)









Increasing wind loads in case of isolated hills and ridges

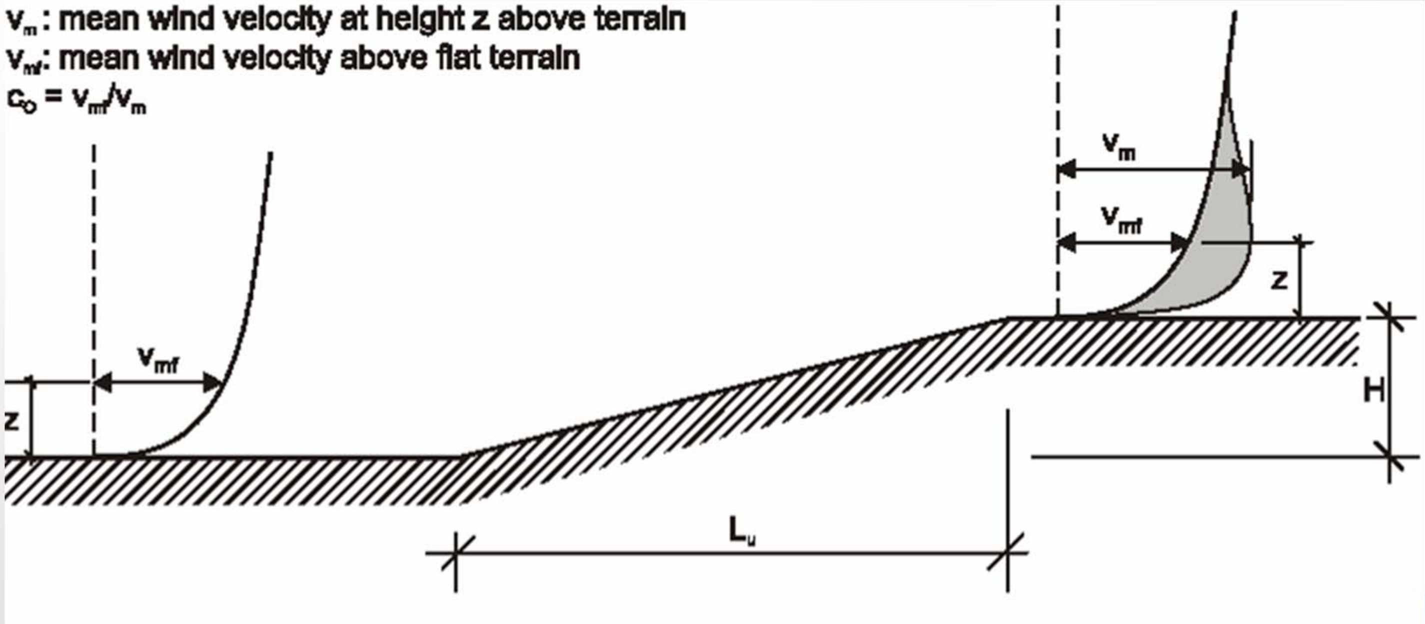


Figure A.1 — Illustration of increase of wind velocities over orography

Increasing wind loads up to 42 % in case of changig topology (isolated hills and ridges)

3. Design calculations for PV systems

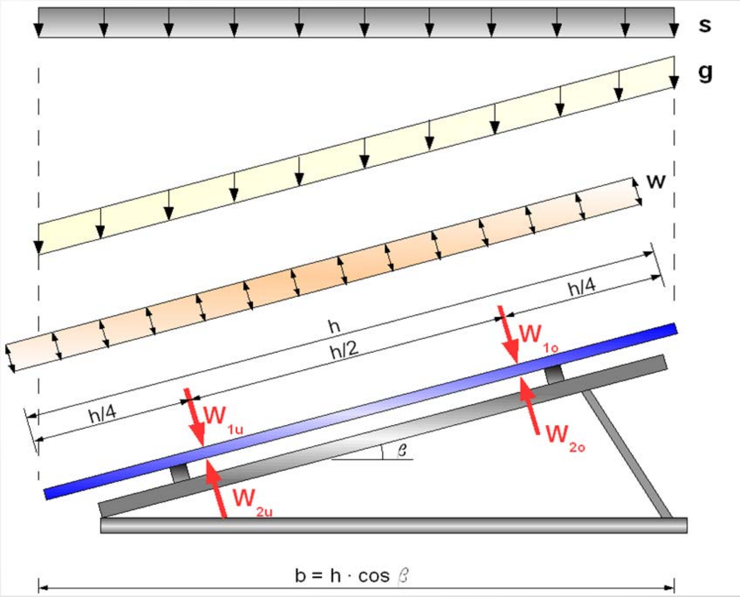
Load combinations

LC 1: 1,35·g + 1,5·s + 0,6·1,5·w

LC 2: 1,35·g + 0,5·1,5·s + 1,5·w

LC 3: 0,9·g + 1,5·w

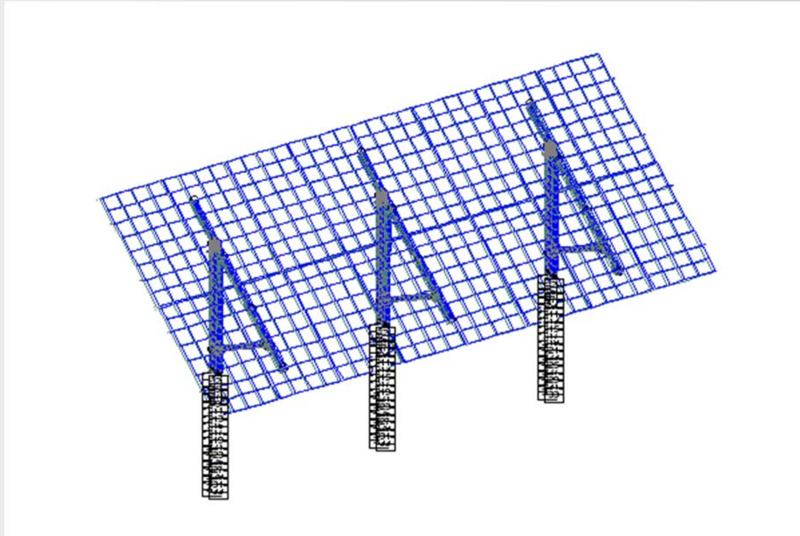
(uplift)

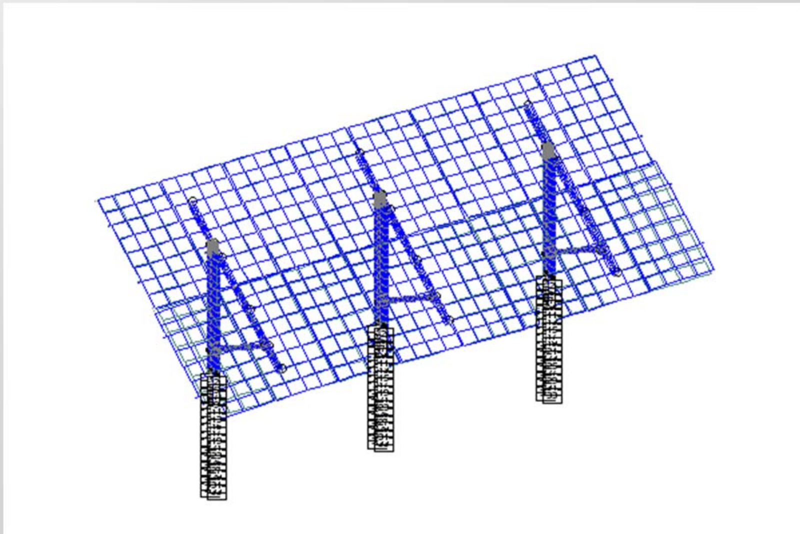


Verifications

- tilting
- dragging
- uplift

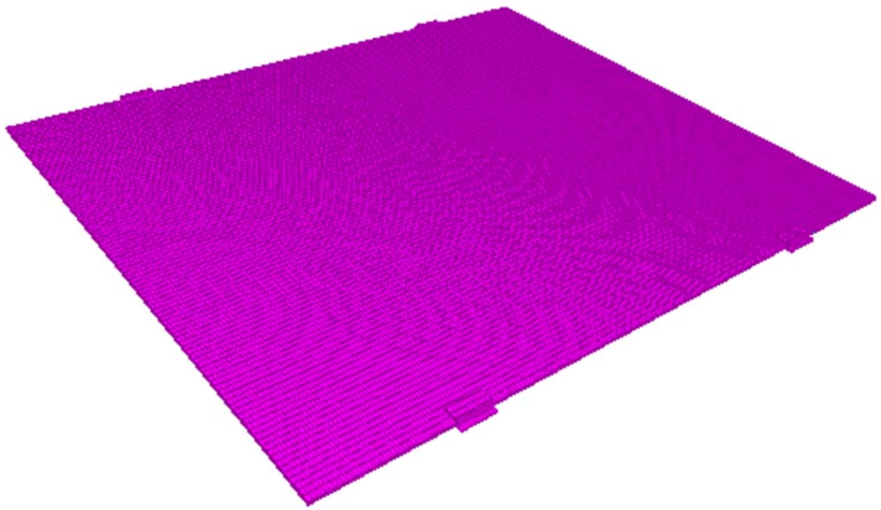
Wind-induced vibrations / seismic design

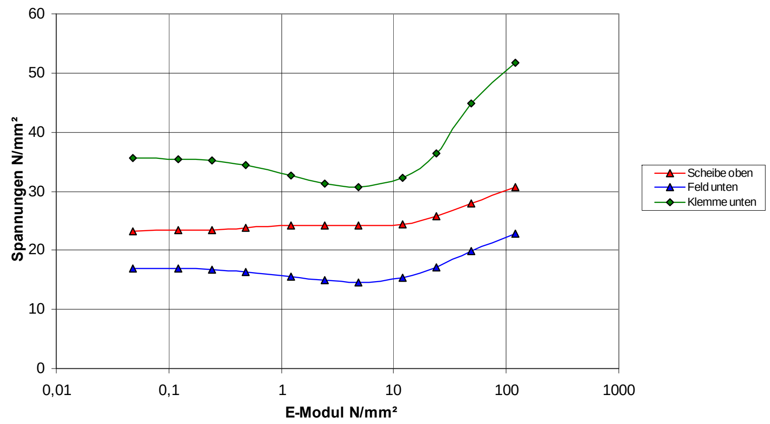


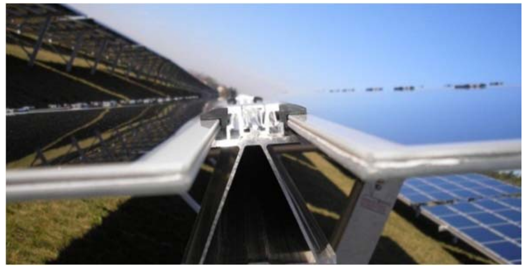


Stress calculations for frameless modules

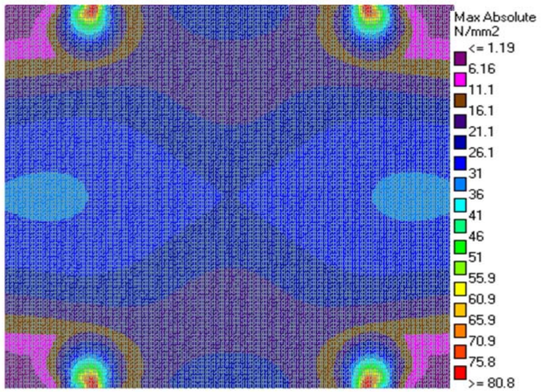
Numerical model

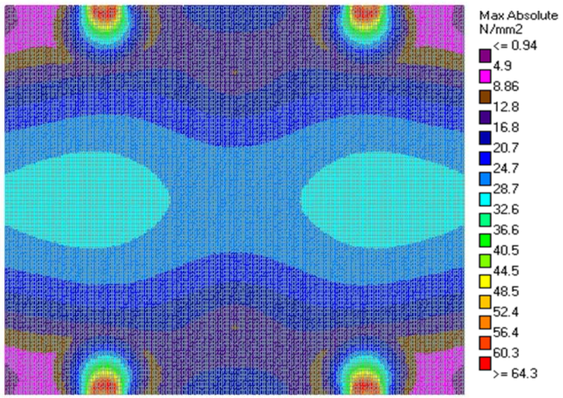


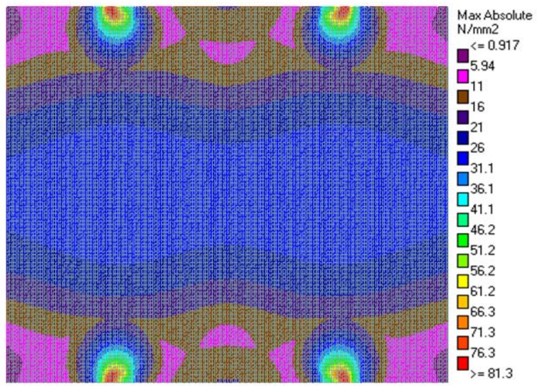




Stress calculations for thin-film modules







4. Decision criteria for substructure selection

Material (dimensioning acc. to basic material standards)

Aluminum

+ low selfweight
+ shaping by extrusion process
+ easy to install (tolerance equalization)
+ remaining value
- floating material prices
- low youngs modulus

Steel

+ availability / well-proven solutions
- corrosion protection
- mounting effort
- high weight

Timber

+ cost-saving for self-mounting
- durability
- contour accuracy

5. Foundation concepts for ground mounted Systems

Pile-driven posts

- •Pull-out capacity (vertical)
- •Horizontal stiffness
- •Bending moment in posts
- •Drilling in case of rocks
- •Chemical composition (corrosion)

Screw foundations

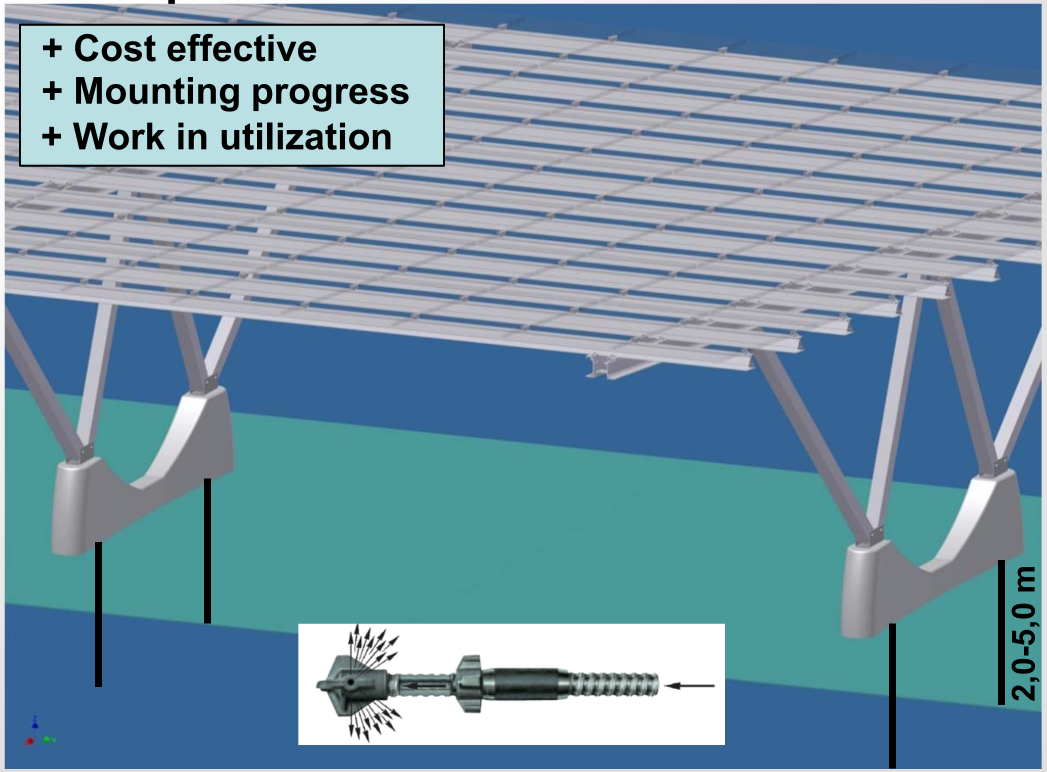
- •Pull-out capacity
- •No horizontal stiffness
- •Axial forces
- •Drilling in case of rocks
- •Chemical composition (corrosion)

Concrete foundation

- •Pressure stability of the soil
- •Sensitivity of the top soil towards water
- •Aggressive soil

Foundation concepts for Carport Systems (Park@Sol)

Micro piles



Concrete foundations

- + Possible for most soil conditions
- - Cost intensive (material)
- - Mounting progress
- - Damage of existing parking lots

6. Mounting progress of different foundation concepts

Ground mounted Systems

Ram-driven posts

1 MW/week

Concrete

1 MW/3 weeks (In situ concrete)

1 MW/2 weeks (precasted)

Carportsystem Park@Sol

Micropiles

1 MW/2 weeks

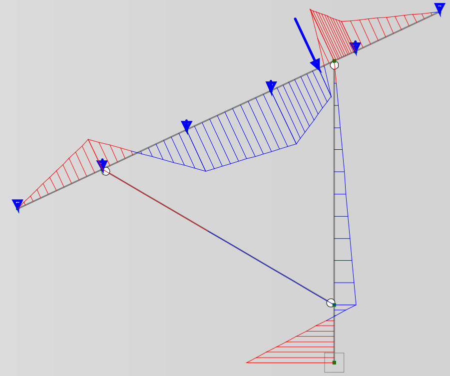
excluding corrugated sheets

Concrete

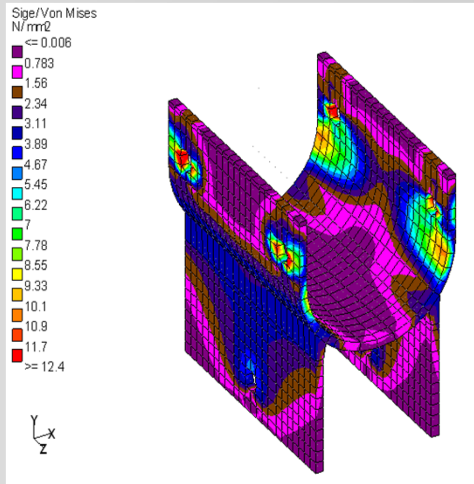
1 MW/6 weeks

including corrugated sheets

7. Conclusions



- Design calculations according to national standards
- Safety standards have to be verified for
  - Authorities
  - Insurance
  - Banking
- Target: Minimum BOS costs
  - Material cost
  - Mounting effort
  - Maintenace over life time
- Ram systems can be mounted significant faster
- The suitable system depends on soil contitions



Thanks for your attention